ISSN: 2595-1661

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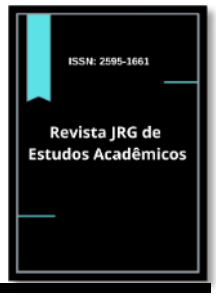

Digital protocol exocad in restorative dentistry: efficiency, personalization, and clinical predictability

DOI: 10.55892/jrg.v8i19.2471
ARK: 57118/JRG.v8i19.2471

Recebido: 15/09/2025 | Aceito: 24/09/2025 | Publicado *on-line*: 25/09/2025

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Abstract

Digital transformation in restorative dentistry has revolutionized clinical and laboratory workflows, providing greater accuracy, efficiency, and treatment predictability. Among the available technologies, Exocad (DentalCAD) stands out as one of the most versatile and widely used platforms, integrating intraoral scanning, cone-beam computed tomography (CBCT), facial imaging, and functional records within a single digital environment. This study conducted a narrative review with a critical and integrative approach, structured using the SALSA framework (Search, AppraisaL, Synthesis, and Analysis), covering publications from 2018 to August 2025. Searches were performed in the PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect databases and institutional repositories of manufacturers and dental associations. The results indicate that Exocad use leads to a significant reduction in clinical and laboratory time, enhanced interdisciplinary communication, and greater esthetic and functional predictability of restorations compared to conventional methods. However, key limitations were identified, including high implementation costs, the need for continuous professional training, and a lack of long-term clinical studies. It is concluded that Exocad has a high disruptive potential in restorative dentistry, representing an essential tool for more efficient and personalized care, although its adoption must be supported by robust scientific evidence and standardized protocols.

Keywords: Restorative Dentistry; Digital Workflow; CAD/CAM; Exocad; Clinical Predictability.

1. INTRODUCTION

Restorative dentistry has been profoundly impacted by the transition to digital workflows. Since the advent of CAD/CAM technology in the 1970s, pioneered by François Duret, these innovations have progressively enhanced the accuracy, efficiency, and convenience of restorative procedures (DURET, 1971; DIGITAL DENTISTRY, 2025). Within this transformative context, Exocad (DentalCAD) has emerged as a robust, versatile, and user-friendly platform, recognized for its intuitive interface, short learning curve, and high productivity, particularly in the design of complex structures such as implant-supported prostheses and bar frameworks (NGAI, 2018).

A key strength of Exocad lies in its interoperability, with the ability to accept open data formats (STL, OBJ, PLY), enabling seamless integration with virtually any intraoral scanner, milling unit, or 3D printer. This interoperability supports the creation of “virtual patients” for personalized restorative planning, allowing clinicians and technicians to handle intraoral scans, CBCT data, facial images, and occlusal records within a unified digital environment (EXOCAD, 2025).

Recent reviews indicate that fully digital workflows, encompassing image acquisition, virtual planning, CAD/CAM fabrication, and final delivery, result in substantial improvements in restoration accuracy, time savings, and patient satisfaction, with fewer post-insertion adjustments and enhanced treatment predictability (ALGHAULI et al., 2025; DIGITAL DENTISTRY, 2025). Moreover, the integration of artificial intelligence (AI) into CAD systems shows promising potential for optimizing diagnostics and improving planning accuracy; however, appropriate regulation and clinical validation remain essential to ensure safety and reliability (ALGHAULI et al., 2025).

In daily clinical practice, Exocad has demonstrated a direct impact on dentist-laboratory communication. Features such as the Smile Creator module for in-CAD esthetic planning allow real-time conversion of 2D photographs into 3D simulations, enhancing treatment predictability, minimizing rework, and increasing patient satisfaction (EXOCAD SMILE CREATOR, 2025). Clinical reports also show significant efficiency gains; for instance, in chairside procedures, the use of Smile Creator combined with digital wax-up enables faster esthetic outcomes and streamlined laboratory-clinic communication (TADROS, 2022).

The technologies associated with Exocad have also benefited from advancements in 3D facial imaging. Systematic reviews reveal that when facial scanners are integrated with intraoral scanning and CBCT, they provide more accurate diagnostics, individualized planning, and advanced esthetic assessments. Nonetheless, barriers such as high costs and the lack of standardized protocols still hinder widespread adoption, particularly in smaller practices (SHUTO et al., 2025). These methodological limitations complicate comparisons across studies and delay broader implementation.

Despite the evident technical progress, several challenges remain: variability in accuracy among different scanner-software combinations (e.g., data loss when converting proprietary formats to STL can compromise restoration fidelity) (EROZAN; OZAN, 2020); the need for long-term clinical validation; high acquisition and training costs; and ethical and regulatory considerations associated with incorporating AI into restorative workflows (ALGHAULI et al., 2025).

Given this promising yet complex scenario, the Exocad digital protocol emerges as a tool offering operational efficiency, clinical personalization, and enhanced restorative predictability, with significant disruptive potential in restorative

dentistry. However, consolidating its validity requires critical appraisal based on robust, comparative, and long-term evidence to ensure its adoption is supported by scientific rigor, technical competence, and patient safety.

2. METHODOLOGY

This review adopted a narrative design with a critical and integrative approach, structured according to the SALSA framework (Search, AppraisaL, Synthesis, and Analysis), which is particularly suitable for contexts in which evidence is heterogeneous and dispersed across scientific articles, clinical guidelines, and technical reports. This methodological model ensures transparency in search, appraisal, and synthesis processes and is recommended for consolidating fields undergoing rapid technological evolution and with direct clinical impact, such as digital protocols applied to restorative dentistry (GRANT; BOOTH, 2009; SNYDER, 2019).

The search covered the period from 2018 to August 2025, encompassing the evolution of CAD software applied to dentistry, with emphasis on Exocad (DentalCAD) and its integration into comprehensive digital workflows. Academic databases PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and Google Scholar were consulted, in addition to institutional repositories from dental associations and software manufacturers (e.g., *exocad.com* and *dentaledx.com*), prioritizing documents with scientific validity and clinical applicability (LEPIDI et al., 2024; EXOCAD, 2025).

The search strategy employed descriptors in English and Portuguese combined with Boolean operators: *("Exocad" OR "DentalCAD") AND ("Restorative Dentistry" OR "Odontologia Restauradora")*, *("Digital Workflow" AND "CAD/CAM")*, *("Smile Creator" AND "Esthetic Planning")*, and *("Digital Dentistry" AND "Predictability")*. The strategy was iterative, with progressive refinements through pilot testing to ensure inclusion of relevant and up-to-date studies (SANTOS; PIMENTA; NOBRE, 2007).

Inclusion criteria: (i) original articles, case studies, systematic and integrative reviews addressing the use of Exocad or digital workflows in restorative dentistry; (ii) publications between 2018–2025; (iii) texts in English, Portuguese, or Spanish; (iv) full-text access. Exclusion criteria: laboratory-only studies with no clinical application; opinion pieces without scientific basis; digital technologies unrelated to Exocad (FRONTIERS IN DENTAL MEDICINE, 2025; SHUTO et al., 2025).

Selection and appraisal: screening was performed through title and abstract review, followed by full-text reading of eligible articles. For institutional sources, the date of last update, clinical scope, and compliance with international digital dentistry standards were verified. Empirical studies were assessed for methodological clarity, clinical applicability, and relevance to restorative dentistry (GAUDÊNCIO; FILHO, 2020; ALGHAULI et al., 2025).

Data extraction and synthesis (Synthesis/Analysis): from each source, the following were collected: study type, year, country, objective, characteristics of the digital protocol, integration of Exocad with other devices, clinical indicators (execution time, accuracy, predictability, patient satisfaction), and reported limitations. The synthesis was thematic, structured into four axes: (i) integration and interoperability of Exocad in digital workflows; (ii) clinical impact and efficiency; (iii) esthetic and functional predictability; (iv) challenges and future perspectives (EXOCAD, 2025; LEPIDI et al., 2024; ALGHAULI et al., 2025).

Limitations: as this is a narrative review, no meta-analysis was performed, and heterogeneity among studies is acknowledged. To mitigate bias, a wide range of databases was explored, recent studies were prioritized, and cross-checking between clinical evidence and technical documents was carried out, in accordance with methodological recommendations for integrative reviews (GRANT; BOOTH, 2009; SNYDER, 2019).

3. RESULTS AND DISCUSSION

The integrative analysis of the selected studies revealed that the adoption of **Exocad (DentalCAD)** in restorative dentistry has fostered a **paradigm shift in clinical and laboratory workflows**, delivering significant gains in **digital integration, operational efficiency, and esthetic and functional predictability**. However, challenges related to **standardization, costs, and robust clinical evidence** still limit its full potential.

3.1 Integration and Interoperability in Digital Workflows

Exocad's **interoperability** has proven to be one of its most distinctive advantages. By enabling the integration of multiple devices and digital formats (STL, OBJ, PLY), the software supports the creation of a **"virtual patient,"** a crucial resource for multidimensional planning that combines anatomical, functional, and esthetic data in a single platform (LEPIDI et al., 2024; EXOCAD, 2025). Studies demonstrate that such integration minimizes cumulative errors and ensures greater consistency between diagnosis, planning, and execution (FRONTIERS IN DENTAL MEDICINE, 2025).

Furthermore, the ability to interconnect with intraoral scanning systems, cone-beam computed tomography (CBCT), 3D facial capture, and dynamic mandibular records enhances **treatment personalization**, enabling an interdisciplinary approach that bridges prosthetic rehabilitation, facial esthetics, and occlusal function (SHUTO et al., 2025). In complex protocols, such as multiple implants and hybrid prostheses, Exocad has shown improved **surgical and prosthetic predictability**, facilitating communication between clinicians, surgeons, and laboratories (ALGHAULI et al., 2025).

3.2 Clinical Efficiency and Operational Productivity

The reviewed studies report substantial reductions in **chairside and laboratory time** when Exocad is incorporated into restorative workflows. Bevilacqua (2023) demonstrated that digital diagnostic waxing combined with virtual planning streamlines manual procedures and eliminates the need for multiple clinical try-ins, improving **patient satisfaction and treatment predictability**. In **chairside workflows**, Tadros (2022) describes reductions of up to **40% in overall treatment time**, attributed to the direct integration of capture, design, and milling/3D printing stages.

From an operational standpoint, the software's **short learning curve and modular architecture** adapt to users' needs, a decisive factor for its adoption across practices and laboratories of varying sizes (NGAI, 2018; EXOCAD, 2025). Compared to traditional methods, characterized by manual stages and operator variability, digital workflows using Exocad provide **greater stability and reproducibility** (EROZAN; OZAN, 2020).

3.3 Esthetic and Functional Predictability

Esthetic predictability is a cornerstone of contemporary restorative dentistry, and Exocad provides advanced tools to achieve it. The **Smile Creator** module enables realistic 3D simulations from 2D photographs, enhancing patient communication and allowing design adjustments prior to clinical execution (EXOCAD SMILE CREATOR, 2025). This approach positively influences **treatment plan acceptance**, reduces rework, and strengthens patient confidence (TADROS, 2022).

Functionally, studies demonstrate superior **marginal and internal adaptation** in restorations planned digitally, with fewer post-cementation adjustments, translating into **greater clinical longevity** (FRONTIERS IN DENTAL MEDICINE, 2025; EROZAN; OZAN, 2020). Compared to conventional workflows, which rely on manual waxing and silicone guides, Exocad-based digital workflows offer **higher fidelity to virtual planning** and significantly reduce cumulative errors (SHUTO et al., 2025).

3.4 Challenges and Limitations of Adoption

Despite these advancements, the literature highlights several **significant obstacles**. The **high initial cost** of equipment, licenses, and maintenance remains a barrier, particularly in developing countries (ALGHAULI et al., 2025). Additionally, **heterogeneity among scanners, software, and milling systems** can compromise final accuracy, with potential **data loss during conversions** between proprietary and open formats (EROZAN; OZAN, 2020).

Another critical issue is the **scarcity of long-term clinical studies**. Most publications focus on case reports or short-term clinical series, limiting the generalizability of results to broader populations (FRONTIERS IN DENTAL MEDICINE, 2025). While the integration of **artificial intelligence** into Exocad is promising, potentially automating design and occlusal analysis, it still requires **regulatory validation and safety protocols** to ensure responsible clinical implementation (ALGHAULI et al., 2025).

3.5 Clinical Implications and Future Perspectives

The findings of this review indicate that Exocad represents a **milestone in the digital transformation of restorative dentistry**, delivering **efficiency, predictability, and personalization**. Its adoption is expected to expand in the coming years, particularly with the incorporation of **AI-driven automation** and the development of **integrated professional training protocols**. However, **caution is warranted**: **uncritical implementation without robust scientific support may jeopardize treatment safety and effectiveness**.

Therefore, **future research should prioritize multicenter randomized clinical trials with long-term follow-up** to strengthen scientific evidence and ensure that technological advances translate into **consistent and sustainable clinical outcomes** (GAUDÊNCIO; FILHO, 2020; GRANT; BOOTH, 2009).

4. CONCLUSION

This review demonstrated that Exocad (DentalCAD) represents a milestone in the advancement of restorative dentistry, providing substantial benefits in digital integration, clinical efficiency, and esthetic and functional predictability. Its ability to consolidate data from multiple digital sources, such as intraoral scanning, tomography, facial imaging, and mandibular records, within a single environment enables a truly personalized and interdisciplinary approach, meeting the

contemporary demands of dentistry for precision and quality (LEPIDI et al., 2024; EXOCAD, 2025).

The findings analyzed indicate that the use of Exocad significantly reduces clinical and laboratory time, minimizes post-operative adjustments, and increases patient satisfaction, while also enhancing communication among professionals and laboratories, positively influencing the predictability and longevity of restorations (BEVILACQUA, 2023; TADROS, 2022). However, major barriers remain, including high initial costs, the need for continuous technological updates, and the lack of multicenter, long-term clinical studies to robustly confirm its superiority over conventional methods (EROZAN; OZAN, 2020; ALGHAULI et al., 2025).

Therefore, it is recommended that the implementation of Exocad be accompanied by continuous professional training, standardization of digital protocols, and gradual integration into academic curricula, preparing future dentists for the digital reality. Furthermore, future research should prioritize randomized clinical trials and long-term comparative studies to evaluate not only technical effectiveness but also economic impact, patient satisfaction, and sustainable clinical outcomes (GAUDÊNCIO; FILHO, 2020; GRANT; BOOTH, 2009).

In conclusion, the Exocad digital protocol holds disruptive and transformative potential in restorative dentistry, establishing itself as an essential tool for more efficient, personalized, and predictable care. Nonetheless, its adoption must be grounded in solid scientific evidence to ensure safety, efficacy, and sustainability in clinical practice.

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